# National

# Advanced Drilling and Excavation

# Technologies Program

**Fourth Meeting of Interested Federal Agencies**
**June 24, 1994**

## -- Summary --

**Geothermal Division**
**U.S. Department of Energy**

## DISCLAIMER

# NATIONAL ADVANCED DRILLING AND EXCAVATION TECHNOLOGIES PROGRAM

## Fourth Meeting of Interested Federal Agencies
## June 24, 1994

## -- SUMMARY --

The U.S. Department of Energy (DOE) Geothermal Division hosted the Fourth Meeting of Interested Federal Agencies on June 24, 1994, at DOE Headquarters in Washington, DC. The meeting was attended by representatives from the National Aeronautics and Space Administration, Department of Defense, U.S. Geological Survey, Environmental Protection Agency, National Science Foundation, Massachusetts Institute of Technology, American Society of Mechanical Engineers, Sandia National Laboratories, Waste Policy Institute, and several offices within the Department of Energy. The meeting agenda is provided in Appendix A; the representatives from each organization are listed in Appendix B.

**John (Ted) Mock**, Director of the Geothermal Division, opened the meeting by welcoming the participants and having each representative introduce himself/herself. He stated that the purpose of the meeting was to present the results of a study conducted under the auspices of the National Research Council. At the request of the Geothermal Division, and co-sponsored by DOE's Yucca Mountain Project Office, Office of Energy Research, and Morgantown Energy Technology Center and the Gas Research Institute, the National Research Council formed the Committee on Advanced Drilling Technologies to evaluate the technical and scientific feasibility of advanced drilling and related technologies and to provide recommendations for future work. Dr. Mock stated that the report represents a major milestone in the National Advanced Drilling and Excavation Technologies (NADET) Program. Publication of the final report is expected to be available for distribution in July.

Dr. Mock explained that geothermal energy is an enormous domestic resource with over one million quads of energy; however, there is only about one quad in reserves (reserves being those resources that are technically and economically accessible today). Although geothermal resources are found everywhere, current technology restricts development to areas that have the highest grade resources. He added that geothermal wells can cost two to four times more than an oil or gas well (often in the $800,000 to $1 million range); they are deep and hot, and usually encounter hard rocks and corrosive fluids. To use the abundant, but hard to access, geothermal resources, drilling costs must be reduced. Referring to a drilling cost vs. well depth chart prepared by MIT (included in Appendix C), Dr. Mock pointed out that, with today's technology, drilling costs increase exponentially with depth. Future technologies should focus on achieving a linear relationship between cost and depth.

With the total geothermal budget being $25-30 million annually spread over many areas, Dr. Mock stated that the Geothermal Division cannot afford to fund all of the necessary drilling R&D. Recognizing that others involved with penetrating rock -- such as the mining, petroleum,



3

and construction industries -- experience similar problems, the Geothermal Division has sought to include these entities and has been soliciting their support for the NADET program. One of the first actions taken was to request the National Research Council to review the status of drilling and excavation technologies and to provide guidance.

In his closing statements, Dr. Mock expressed that the need for improved drilling technologies should not be viewed as a major national problem, but as a **major national opportunity**. Current annual expenditures for drilling and excavation are on the order of $1.5 trillion worldwide, and revolutionary drilling systems can make a substantial impact on this sizeable market.

The meeting continued with some updated information about NADET activities. **Allan Jelacic** of the Geothermal Division, and the primary contact for the NADET program, began his briefing (Appendix D) by displaying the NADET logo that was selected by the participants at the last meeting. He reiterated that the primary goal of the NADET program is to develop a revolutionary drilling system through the collaborative efforts of industry, university, national laboratory, and various government agency researchers and advisors.

Dr. Jelacic reviewed the three general phases of the NADET program and discussed the feasibility analysis and program planning activities of Phase 1 in more detail. He reported that the program plan prepared by MIT was distributed to industry for review and he received comments about the organization of the program and its content. With regard to the organization of the program, the comments stressed the need for and the importance of industry involvement. The comments on the program content recommended more field testing of developing technologies, and suggested that a ranking of parameters for measuring system performance be established.

Dr. Jelacic presented the current status of the survey that was conducted to determine the level of industry interest in the NADET program. He reported that a total of 250 responses have been received. Of the 80 companies that indicated they would participate in the program, seven companies were willing to provide financial support, 27 to provide laboratory facilities, 30 to provide field test facilities, and 33 to provide equipment.

Some of the other Phase 1 activities mentioned by Dr. Jelacic included the distribution of the third issue of the program newsletter, ***NADET News***; the preparation of a brochure describing the NADET program; and the presentation of NADET information at drilling-related conferences and via publications. Dr. Jelacic informed the participants that a review of Russian literature on novel and advanced rock disintegration techniques was being performed by a group of Russian scientists through a contract with Maurer Engineering. The report will be completed this summer. In addition, he reported that a systems analysis of advanced drilling systems, co-funded by the DOE Geothermal Division and the Morgantown Energy Technology Center, was just

getting started by Sandia National Laboratories. He pointed out that this is the first collaborative effort under the NADET banner.

**Kenneth Pierce** of Sandia provided a brief overview of the systems analysis study. He explained that the basic functions of a drilling system can be described as energy transmission, rock reduction, rock removal, directional control, communication, formation maintenance, and completion. He added that system characteristics include the rate of penetration, cost comparison to current technology, predicted performance and capabilities, technical and financial limitations, and impact on industry. Mr. Pierce stated that the goals of the study are to develop a basic reference for advanced drilling systems and to identify those concepts most promising for further development. A copy of Mr. Pierce's briefing slides is provided in Appendix E.

Dr. Jelacic continued his briefing with a discussion of the Geothermal Division's funding for NADET. He reported that approximately $300 thousand has already been spent on NADET-related activities. He added that $6.4 million, or about 17% of the total FY 1995 budget request for the Geothermal Division, was designated for drilling activities. Of that amount, $2.0 million was earmarked for NADET activities. The remaining $4.4 million was to be used for geothermal-specific R&D, such as slim hole drilling, instrumentation, and lost circulation control.

**Mehmet "Matt" Tumay** of the National Science Foundation inquired if NADET will become a program under the National Science and Technology Council (NSTC). He added that programs pertaining to transportation and civil technologies are currently being conducted through NSTC. He also noted that the Federal Coordinating Council for Science, Engineering, and Technology was terminated. Dr. Jelacic responded that this option was being investigated.

Dr. Jelacic then introduced **Kevin Crowley**, Program Officer with the National Research Council (NRC). Dr. Crowley discussed the study by the Council's Committee on Advanced Drilling Technologies. The Committee met four times over a period of about a year. A workshop, attended by 42 experts with specialties covering all aspects of drilling, was also held to provide additional ideas for the Committee to consider in developing their recommendations. The report prepared by the Committee examines concepts for the entire drilling process including state-of-the-art mechanical and non-mechanical drilling mechanisms; advances in the sciences pertaining to rock-tool interaction; advances in drilling system components; and advances in sensing, guidance, and telemetry. The report also addresses potential opportunities for research and makes recommendations on the scope and direction needed to realize these opportunities. Dr. Crowley related that the Committee defined drilling as a set of processes for breaking and removing rock to produce boreholes, tunnels, and excavations and that drilling is considered a key technology with strategic and societal importance. The national importance of drilling in terms of exploration for and extraction of mineral resources, environmental monitoring, underground excavation, and scientific studies was then reviewed.

**Carl Peterson** of the Massachusetts Institute of Technology remarked that the mining, construction, and oil and gas industries are very fragmented and that this fragmentation hinders the advancement of the NADET program. He added that the DOE cannot carry NADET alone and asked the participants for ideas on how to proceed with the initiative and how to reach national policy decision-makers and high-level government officials.

Dr. Luth responded that the agencies are concerned that if they support NADET, the funds will be redirected from their current efforts. Dr. Mock stated that a national need has been identified, but support from industry is critical to obtain federal funding. He conjectured whether industry really wants an advanced drilling R&D program.

**Howard Clark** of the American Society of Mechanical Engineers cited programs involving the textile and automobile industries as examples of successful industry-government collaboratives. In these cases, the industries approached the government with their needs and with substantial financial commitments and were able to secure federal cost-shared funds. He added that in the past he has brought industry and government to the table to address common needs and offered to assist in bringing industry and government representatives together to discuss NADET. Dr. Mock suggested that late summer or early fall would be an appropriate time for such a meeting.

**Elena Melchert** of DOE's Office of Fossil Energy stated that it would be beneficial to get some of the professional societies to back the NADET initiative and suggested a writing campaign. Dr. Tumay recommended that consideration be given to adding NADET to an existing initiative, such as the Civil Engineering Research Facility's Civil Infrastructure Systems, since a large amount of funding is being sought from the government. **Lynn McLarty** of Dyncorp Meridian remarked that a "mover and shaker" from industry should be promoting NADET so that it is perceived as an industry, rather than a government, effort. This comment was met with general approval by the attendees, but an individual from industry to fill that role was not identified.

Before the meeting adjourned, Dr. Mock asked the participants to submit ideas for projects that could be conducted, especially if funding is limited. He suggested improved bits, drilling fluids, and downhole motors as potential technologies that could produce near-term results. He briefly reviewed some of the advantages that a smart drilling system could offer and the impact that it could have compared to today's drilling technology. Appendix G contains a copy of his slides. Dr. Mock concluded by remarking that "our work is just beginning." He recommended that the next federal agencies meeting be held toward the end of the summer.

**Appendix A**

# National Advanced Drilling and Excavation Technologies Program

## Fourth Meeting
## of
## Interested Federal Agencies

June 24, 1994

Hosted by
Geothermal Division
U. S. Department of Energy

| | | |
|---|---|---|
| 9:30 am | Registration - Room 1E-245<br>Forrestal Building | |
| 10:00 am | Welcome/Introductions | John Mock<br>Department of Energy |
| 10:05 am | Update of Activities Concerning the NADET Program | Allan Jelacic<br>Department of Energy |
| 10:30 am | Summary of National Research Council Study of Advanced Drilling Technologies | Kevin Crowley<br>National Research Council |
| 11:00 am | Open Discussion | All |
| 11:30 am | Closing Remarks | John Mock |

## Appendix B

## NATIONAL ADVANCED DRILLING AND EXCAVATION TECHNOLOGIES PROGRAM

### Fourth Meeting of Interested Federal Agencies
### June 24, 1994

**Participants:**

American Society of Mechanical Engineers
- Howard Clark

Department of Defense
- George Gazonas, Army Research Laboratory
- Paul Senseny, Defense Nuclear Agency

Department of Energy - Geothermal Division
- Matthew Davis
- Allan Jelacic
- John "Ted" Mock

Department of Energy - Other Offices
- David Biancosino, Environmental Restoration and Waste Management
- Stephan Brocoum, Civilian Radioactive Waste Management
- Charles Brown, Fossil Energy
- Grover "Skip" Chamberlain, Environmental Restoration and Waste Management
- William Luth, Energy Research
- Elena Melchert, Fossil Energy
- Albert Yost, Morgantown Energy Technology Center

Department of Interior
- Ray Wallace, Geological Survey

Dyncorp Meridian
- Lynn McLarty

Environmental Protection Agency
- Steve Souders

Federal Transit Administration
- Jeffrey Mora

Louisiana Transportation Research Center
- Mehmet Tumay

**Participants (continued):**

Massachusetts Institute of Technology
- Carl Peterson, Department of Mechanical Engineering
- Jefferson Tester, Energy Laboratory

National Aeronautics and Space Adminstration
- Steve Brody

National Research Council
- Kevin Crowley, Board on Earth Sciences and Resources
- Mahadevan Mani, Energy Engineering Board
- Jonathan Price, Board on Earth Sciences and Resources

National Science Foundation
- Priscilla Nelson

Princeton Economic Research, Inc.
- Michele DeStefano
- Perle Dorr
- Eyob Easwaran
- Alex Moore

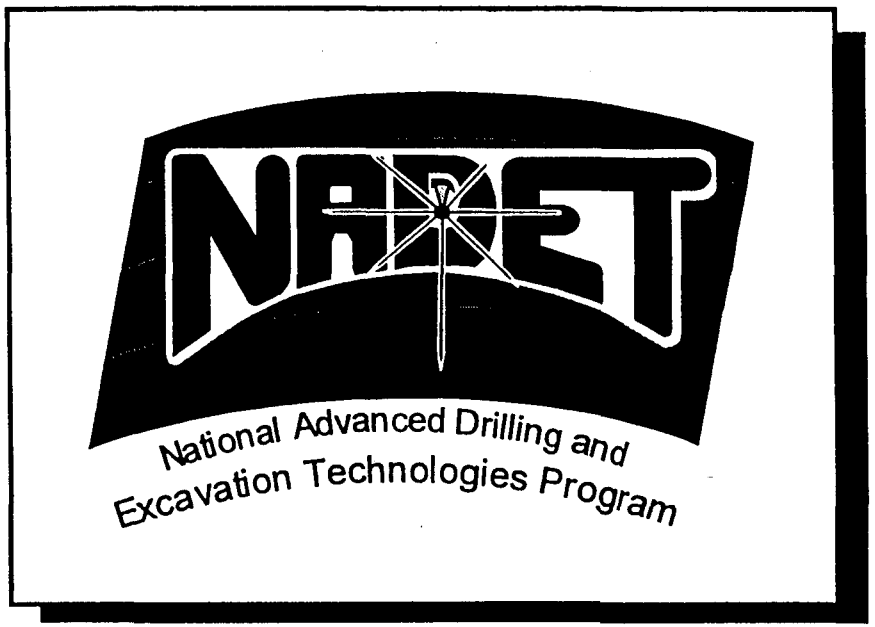
Research Opportunities Management
- Peter Smeallie

Sandia National Laboratories
- James Dunn
- Kenneth Pierce

Waste Policy Institute
- Robert Vagnetti

# Appendix C

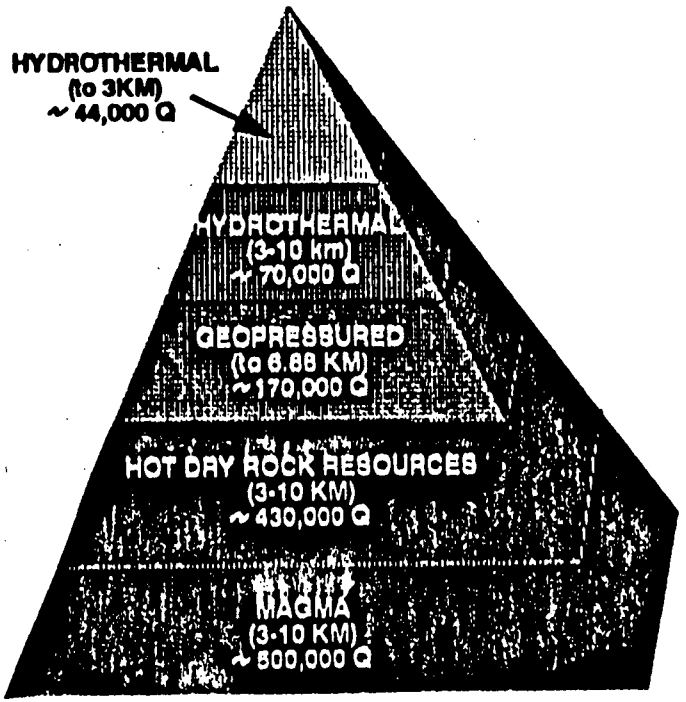
## Introductory Slides Presented by John "Ted" Mock, Department of Energy Geothermal Division




# A Collaborative R&D Initiative

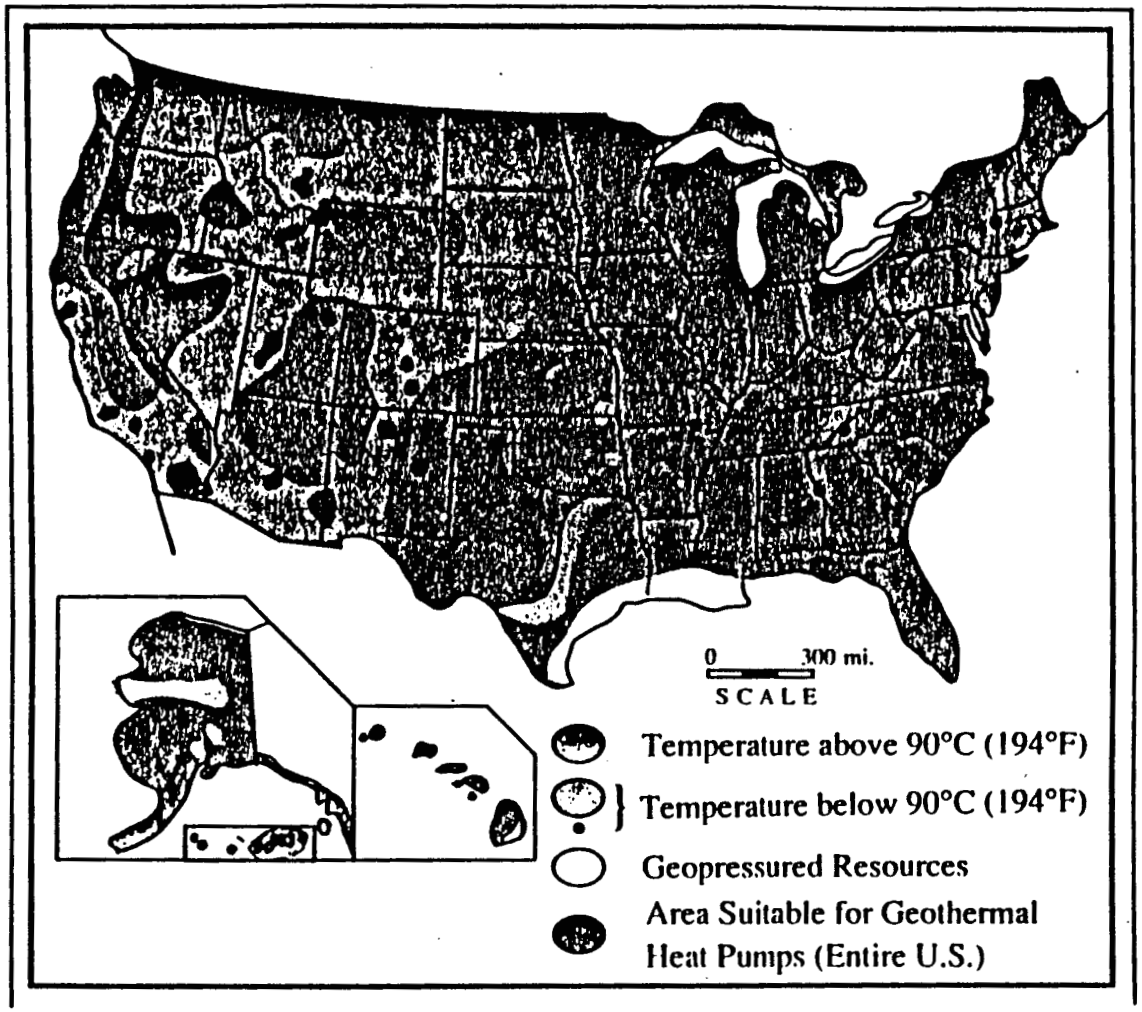
John E. Mock, Director • Geothermal Division
Office of Renewable Energy Conversion • U.S. Department of Energy

# Geothermal is a Large Domestic Source of Energy

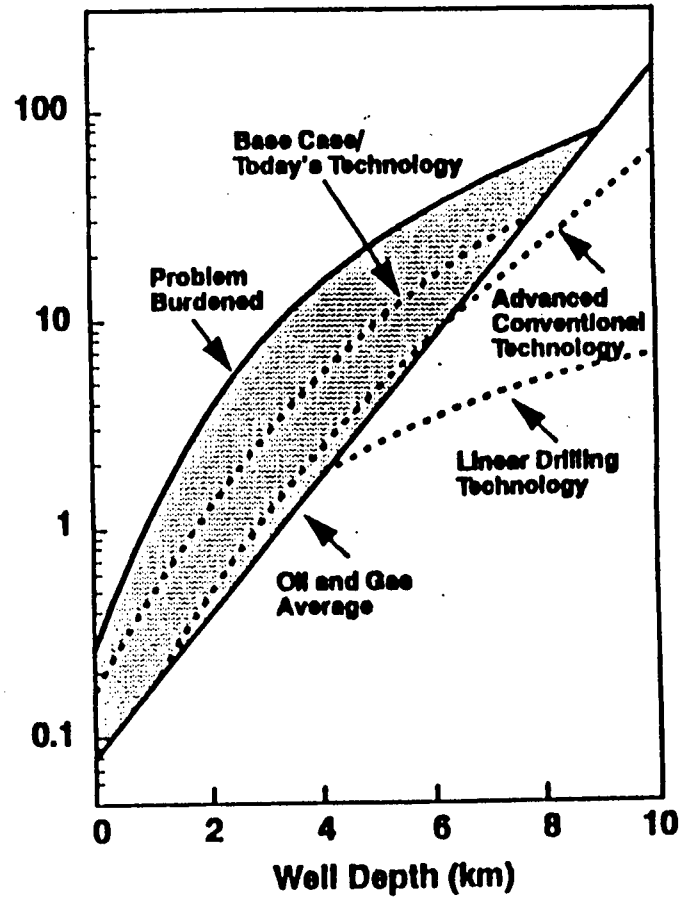



(Estimated Total = $1.2 \times 10^6$ Q)

RDE02

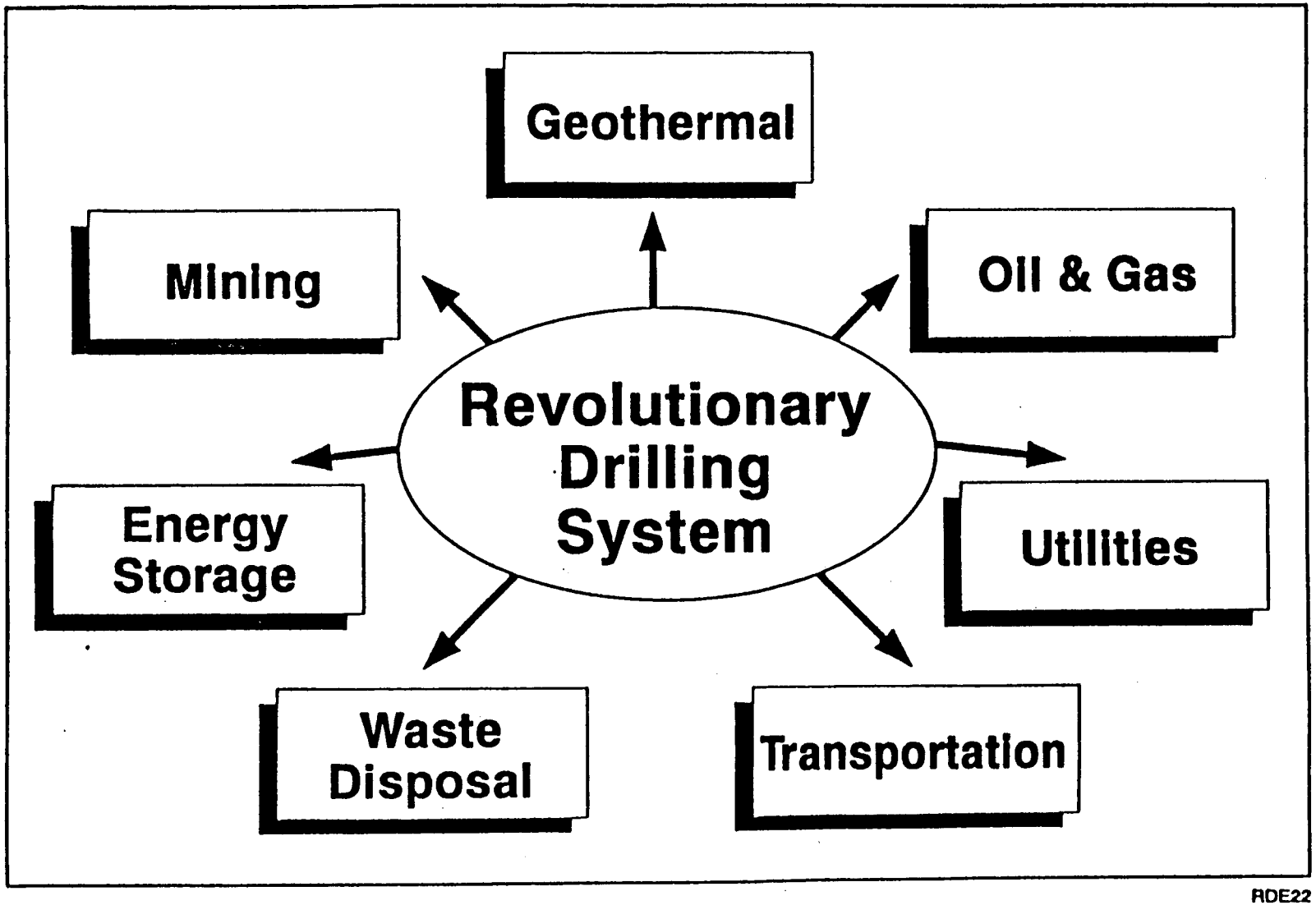

0 300 mi.
SCALE
Temperature above 90°C (194°F)
Temperature below 90°C (194°F)
Geopressured Resources
Area Suitable for Geothermal Heat Pumps (Entire U.S.)

# Drilling Costs for Completed Geothermal Wells




SOURCE:
Tester and Herzog, MIT Energy Laboratory, 1992

RDE05


Geothermal
Mining
Oil & Gas
Revolutionary Drilling System
Energy Storage
Utilities
Waste Disposal
Transportation
RDE22

# Cross - Industry Commonalities

- Breaking or penetrating rock
- Removing rock fragments and/or soil
- Maintaining gauge
- Supporting openings created
- Providing umbilicals and communications to the surface
- Circulating coolants/lubricants

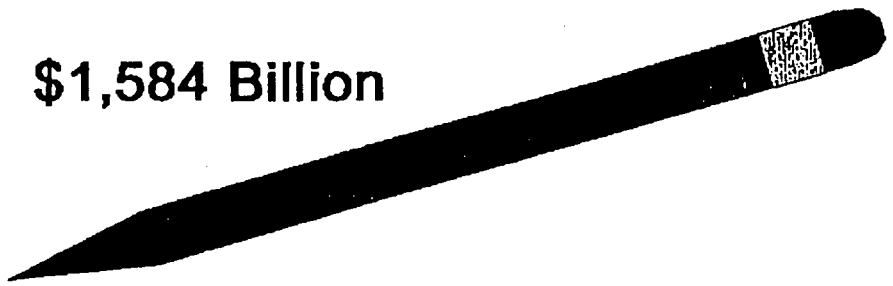
RDE14

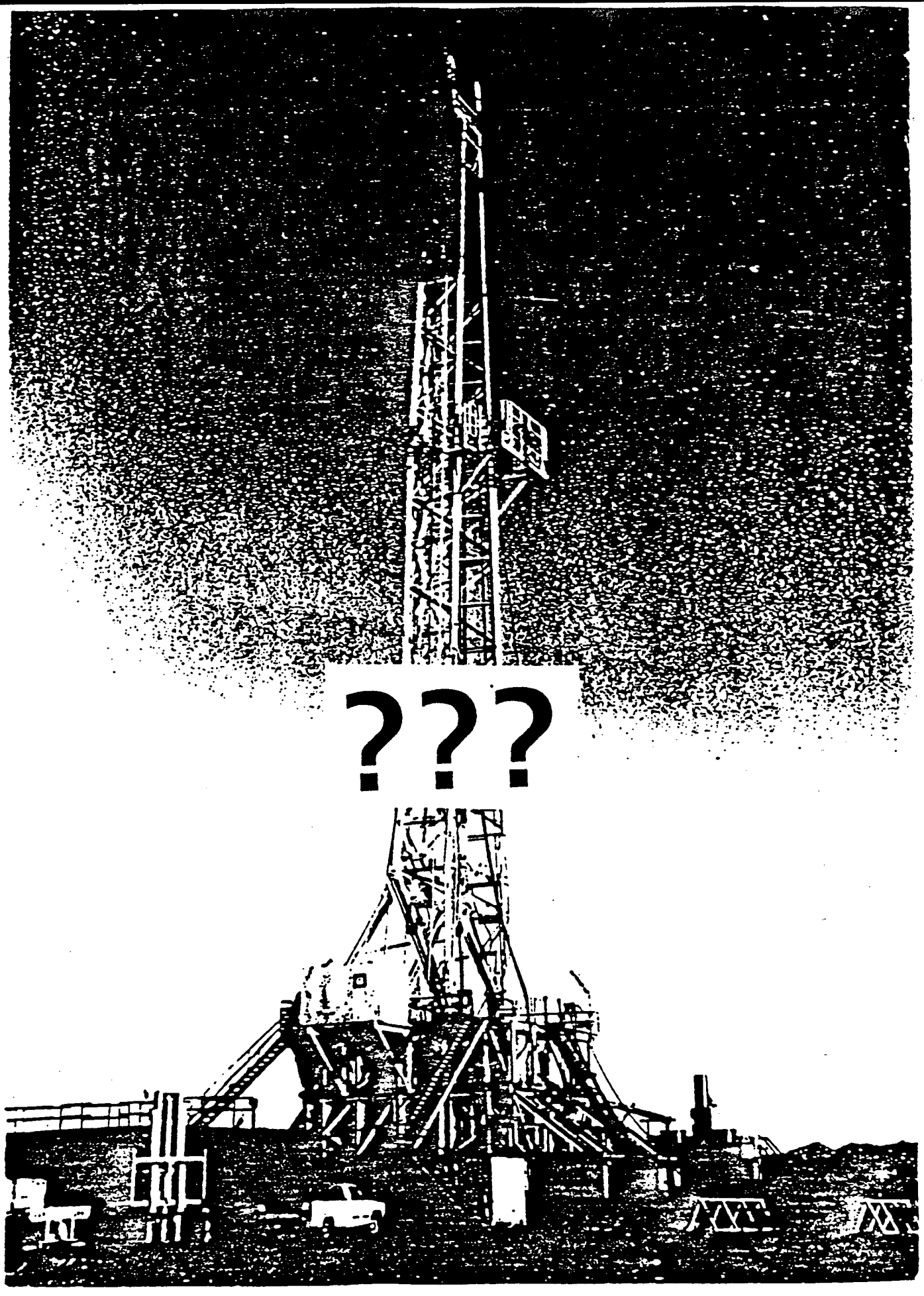
# National Research Council: Study on Advanced Drilling Technologies

- Evaluate the technical and scientific feasibility of advanced drilling and related technologies
- Examine concepts for new mechanical and non-mechanical drilling applications
- Identify potential opportunities for research
- Make recommendations on the scope and direction needed to realize these opportunities

# Estimated Annual Expenditures for Worldwide Drilling and Excavation Activities

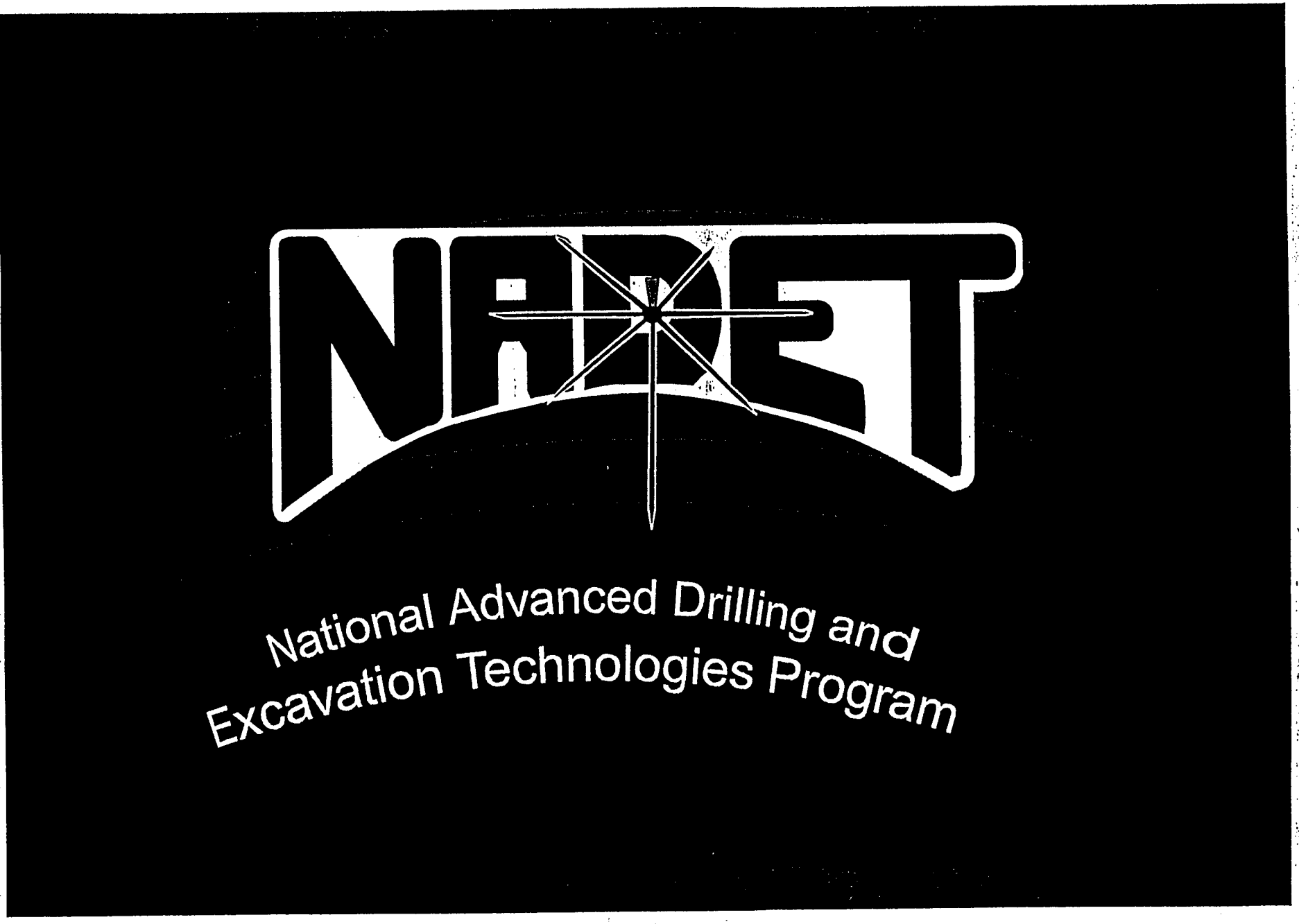
| | |
|---|---|
| Oil & Gas | $82.2 - 100.2 Billion |
| Coal | $120 Billion |
| Civil Tunnel and Underground Facilities | $19.8 - 20.7 Billion |
| Mining, Drilling and Rock Excavation (Total value of crude mineral production) | $1,584 Billion |

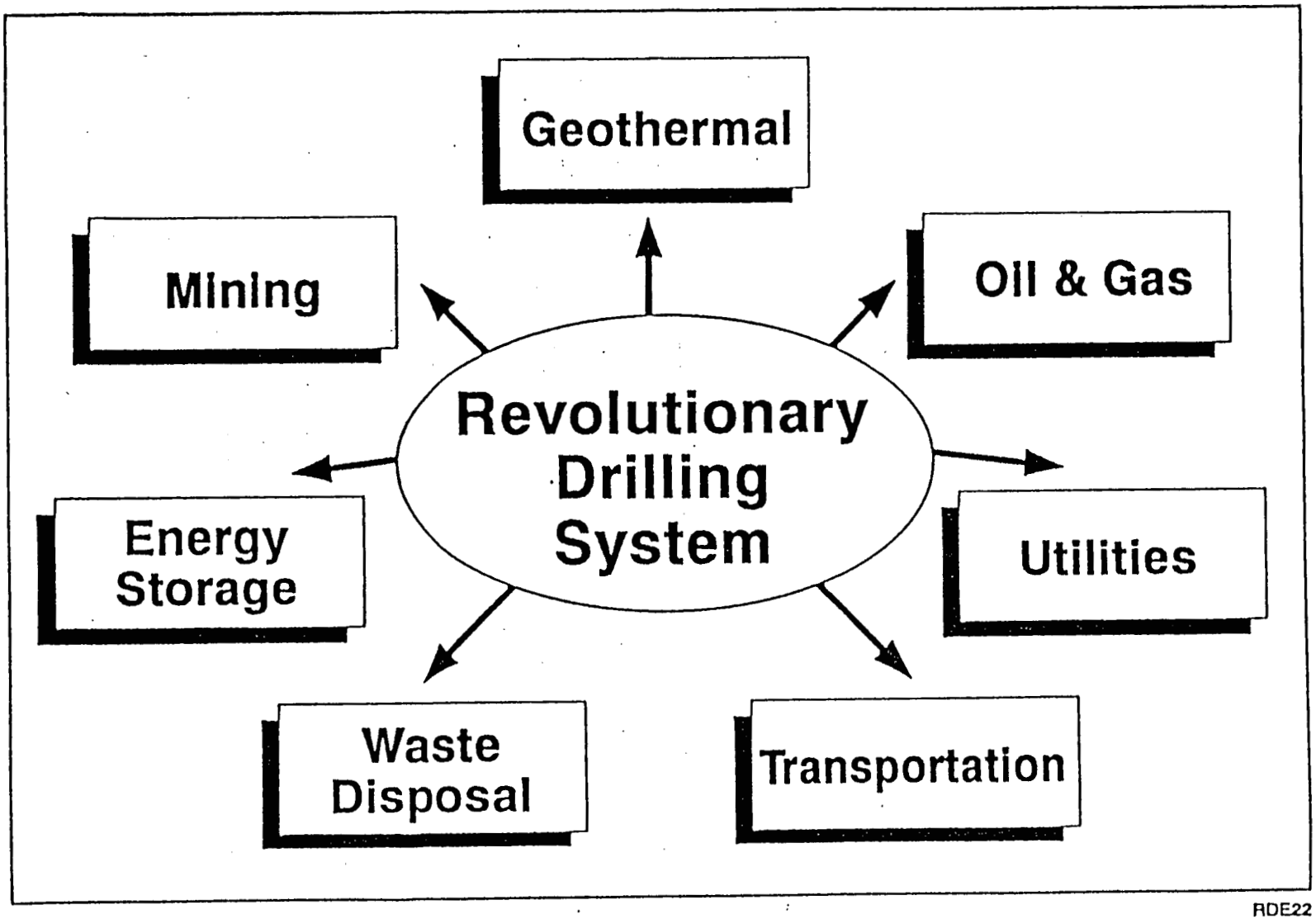




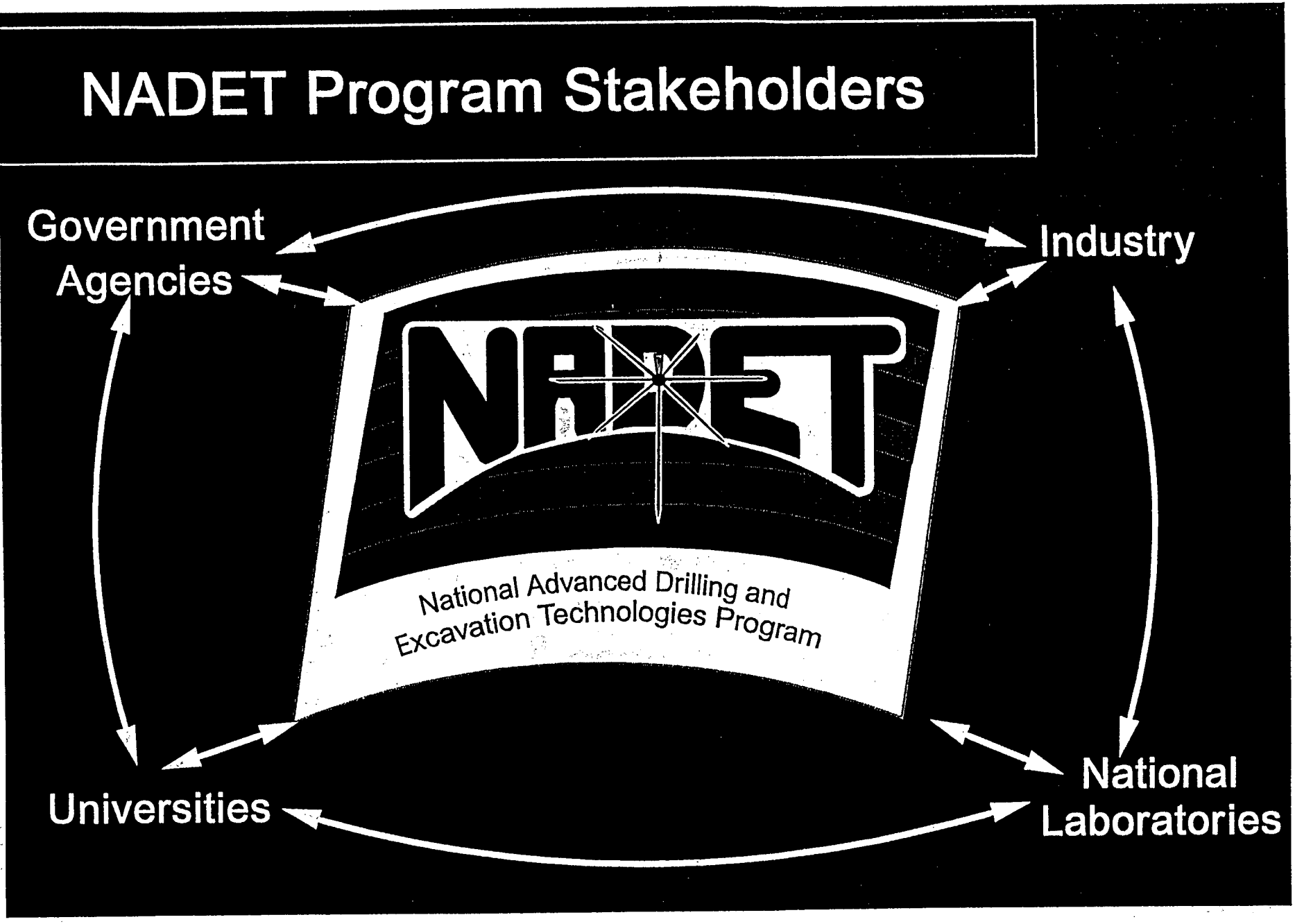
# Appendix D

## Slides Presented by Allan Jelacic, Department of Energy Geothermal Division


NADET
National Advanced Drilling and
Excavation Technologies Program


Geothermal
Mining
Oil & Gas
Revolutionary Drilling System
Energy Storage
Utilities
Waste Disposal
Transportation
RDE22

# NADET Program Stakeholders



# NADET Program Phases

*Phase 1:* *Feasibility Analysis and Program Planning*

*Phase 2:* *Development of Advanced Technologies; Building and Field Testing of Prototype System*

*Phase 3:* *System Commercialization*

# Phase 1 Activities

- Interagency Meetings
- Program Plan and Promotion Strategies
- National Research Council Study
- Industry Survey
- Spreading the Word about NADET
- Background Studies

# Federal Agency Participants

Department of Energy

National Aeronautics and Space Administration

Department of Defense

National Institute of Standards & Technology

Department of Interior

Department of Transportation

National Science Foundation

Department of Commerce

Environmental Protection Agency

Nuclear Regulatory Commission

# Phase 1 Activities

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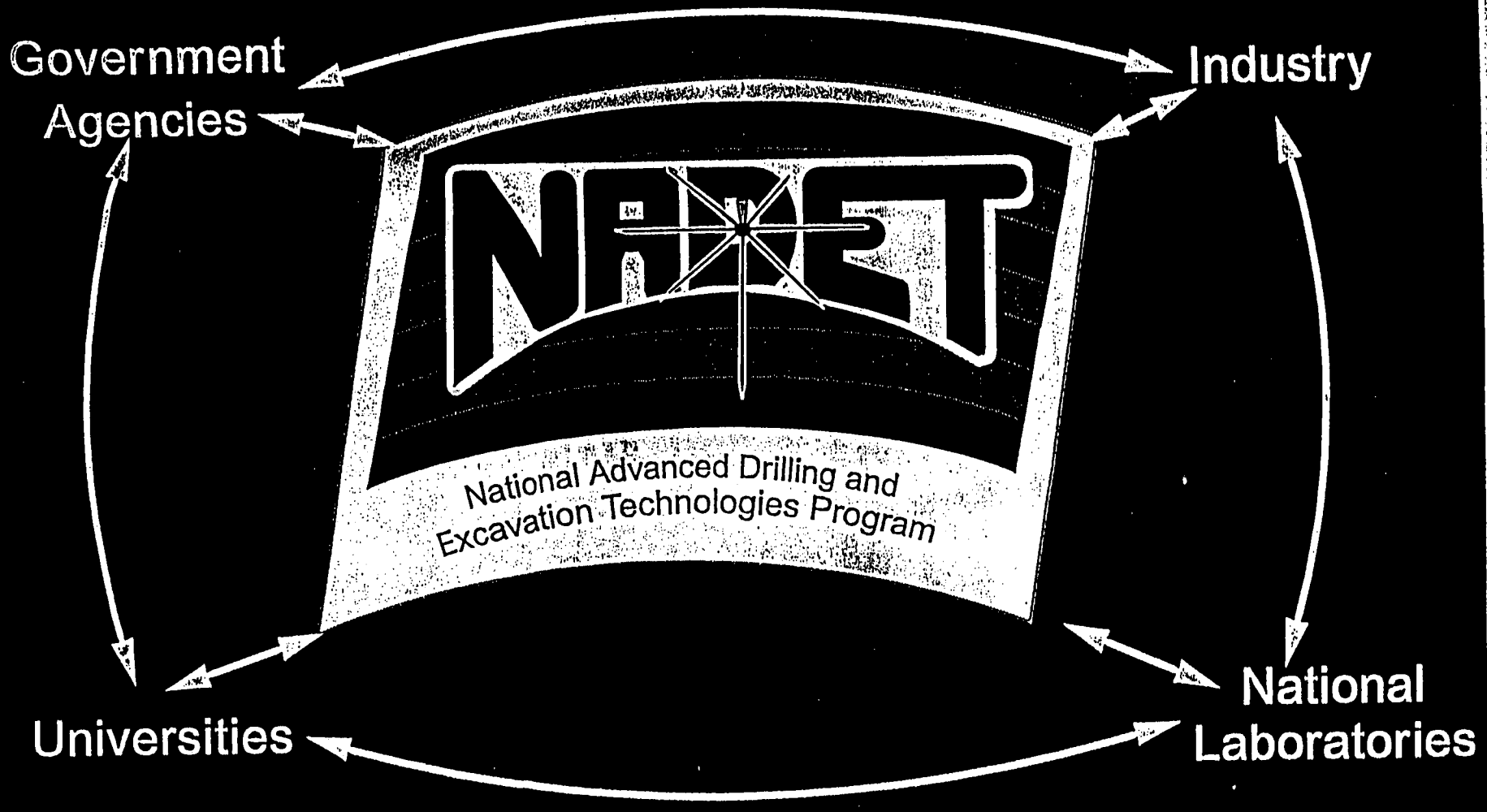

# NADET Program Phases

*Phase 1:* *Feasibility Analysis and Program Planning*

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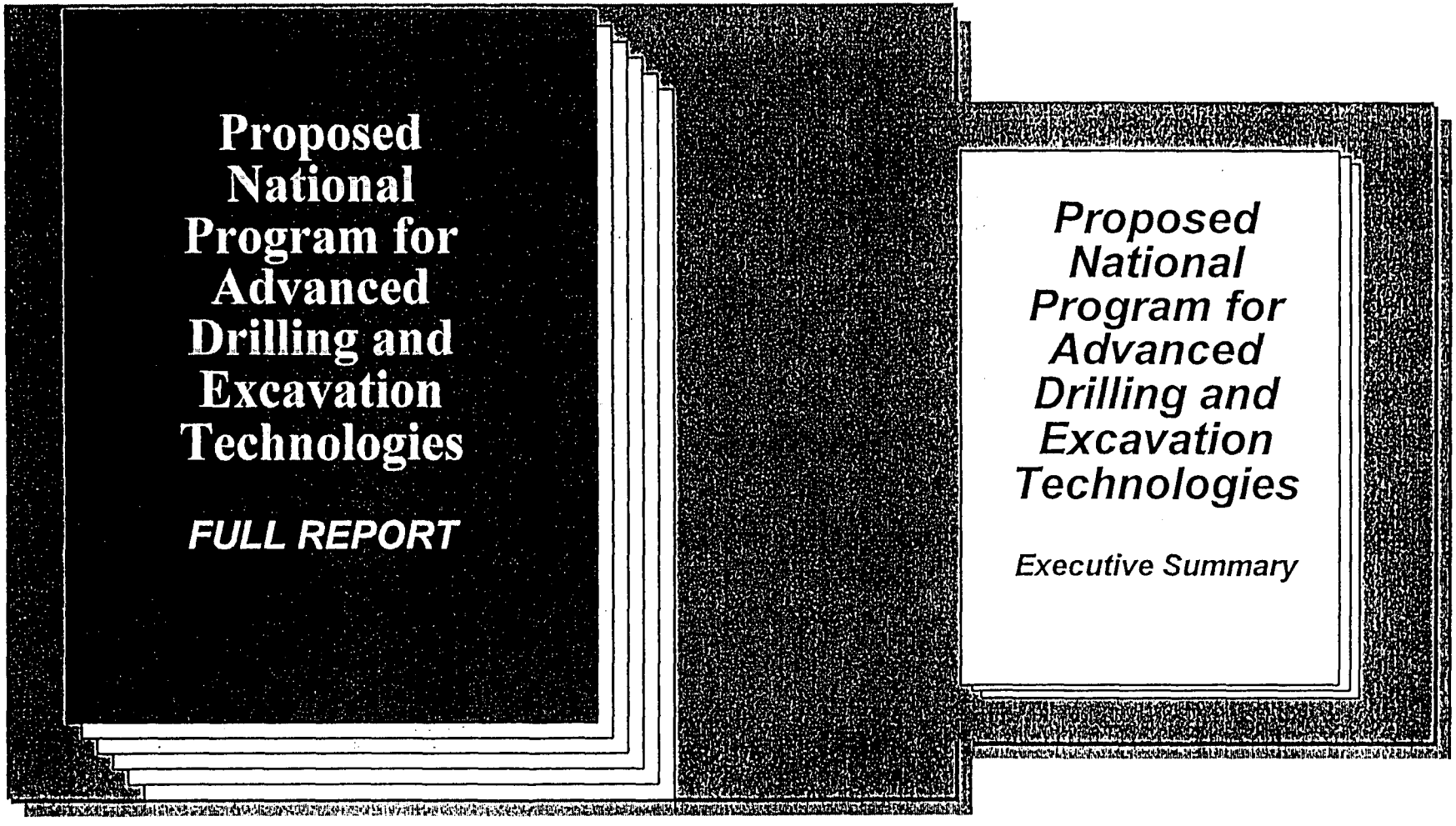
*Phase 3:* *System Commercialization*

# MIT REPORTS


Proposed National Program for Advanced Drilling and Excavation Technologies
FULL REPORT
Proposed National Program for Advanced Drilling and Excavation Technologies
Executive Summary

# Comments on Proposed Program Plan for NADET

- **Organization**
  - Use Trade Organizations and Industrial Societies
  - Involve Industry on a Worldwide Basis
  - Emphasize Technology Transfer; Involve Industry, Especially Small Specialized Firms
  - Provide Funding for Small Research Companies

- **Content**
  - Develop National Field Testing Facility
  - Conduct Field Tests of New Technology by Industrial Users Under Competitive Conditions
  - Focus on Technology for Drilling Large-Diameter Wells in Hard Rock
  - Support Testing of Smart Steerable Drilling Systems Now Under Development by Industry
  - State the Parameters with Which to Measure and Objectively Rank New Technologies

# Phase 1 Activities

- Interagency Meetings
- Program Plan and Promotion Strategies
- National Research Council Study
- Industry Survey
- Spreading the Word about NADET
- Background Studies

# National Academy of Sciences
# Committee on Advanced Drilling Technologies

Dr. Ali S. Argon, Co-Chairman
Massachusetts Institute of Technology

Dr. George A. Cooper
University of California at Berkeley

Dr. Stephen E. Laubach
Texas Bureau of Economic Geology

Dr. James E. Monsees
Parsons Brinckerhoff

Dr. Jean-Claude Roegiers
University of Oklahoma

Dr. Mark D. Zoback
Stanford University

Dr. Neville G.W. Cook, Co-Chairman
University of California at Berkeley

Dr. Michael M. Herron
Schlumberger-Doll Research

Dr. William C. Maurer
Maurer Engineering, Inc.

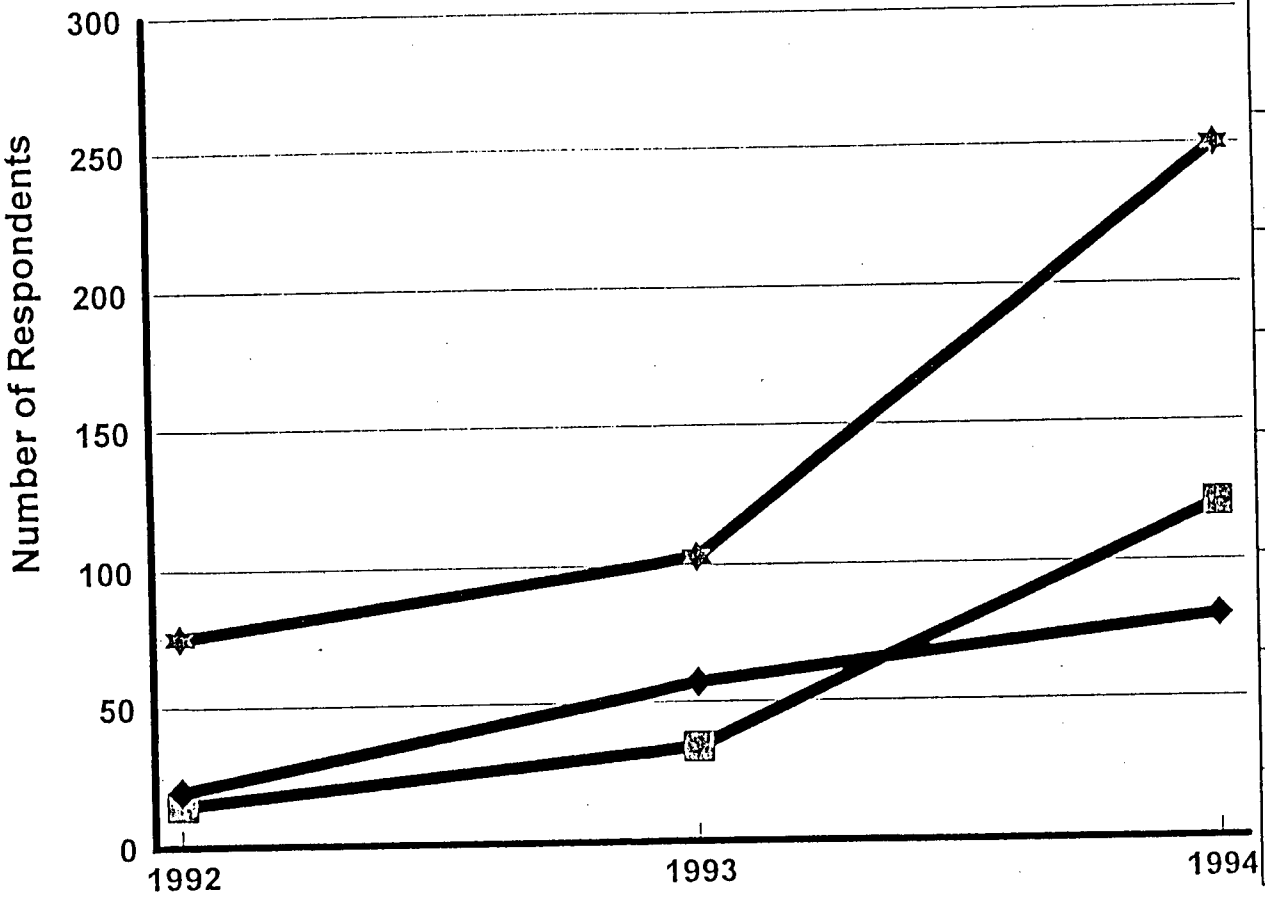
Dr. D. Stephen Pye
UNOCAL Corporation

Dr. Eugene D. Shchukin
Johns Hopkins University

# Phase 1 Activities

- Interagency Meetings
- Program Plan and Promotion Strategies
- National Research Council Study
- Industry Survey
- Spreading the Word about NADET
- Background Studies

# Industry Survey




| Proposed Support | Number of Responses |
|---|---|
| Financial Support | 7 |
| Personnel | 57 |
| Equipment | 33 |
| Laboratory Facilities | 27 |
| Data Bases | 18 |
| Field Testing Facilities | 20 |
| Other | 12 |

# Phase 1 Activities

- Interagency Meetings
- Program Plan and Promotion Strategies
- National Research Council Study
- Industry Survey
- Spreading the Word about NADET
- Background Studies

# Spreading the Word about NADET

- Newsletter
- Industry Meetings / Technical Papers
- Brochure

# Phase 1 Activities

- Interagency Meetings
- Program Plan and Promotion Strategies
- National Research Council Study
- Industry Survey
- Spreading the Word about NADET
- Background Studies

# Background Studies

- Review of Russian Literature
- Systems Analysis

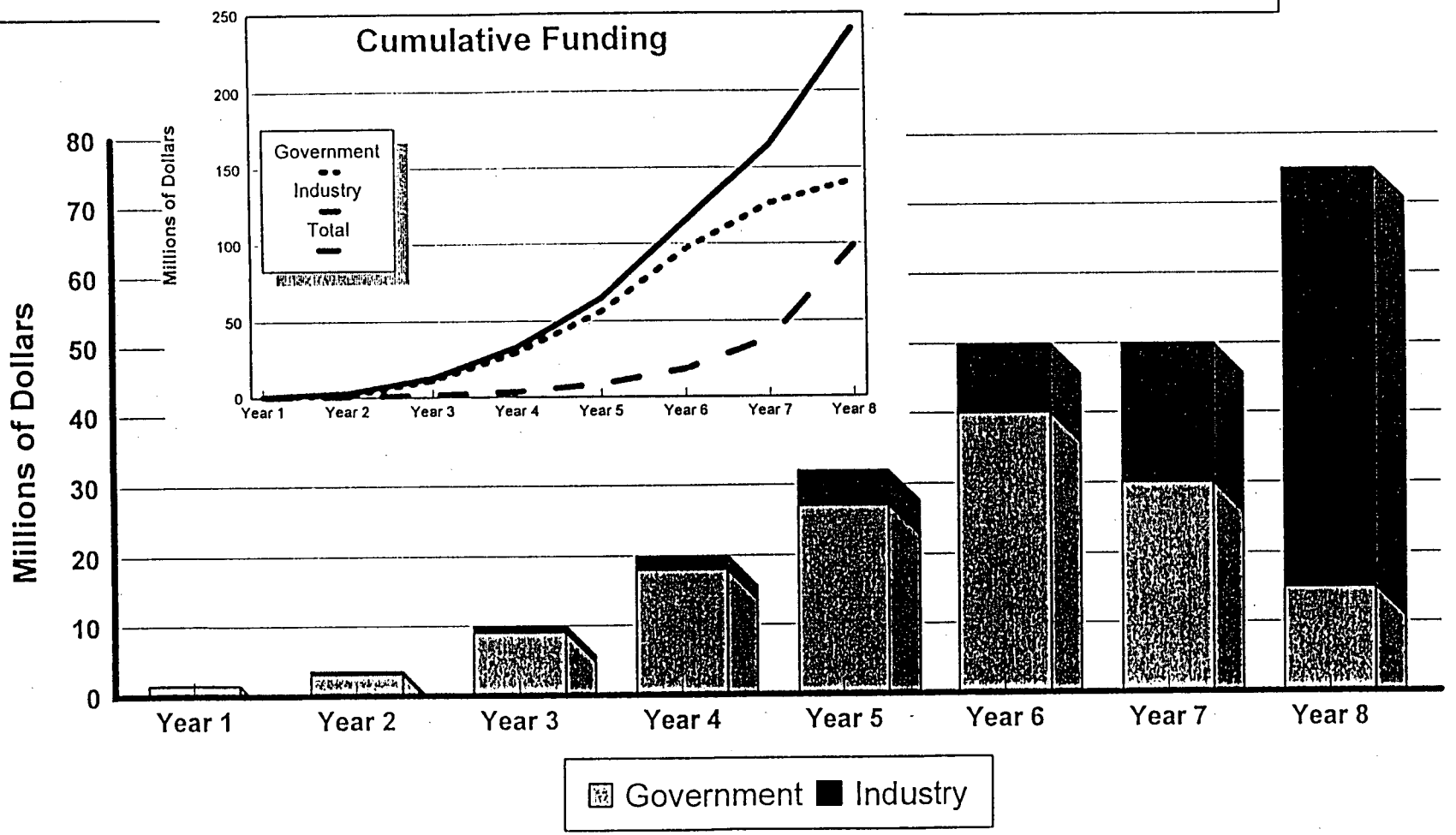
# Novel and Advanced Techniques of Rock Disintegration

- **Summary of Russian R&D Over Past 30 Years**
- **Mechanical Techniques**
  - Vibration
  - Intermittent Drilling
  - Turbodrilling
- **Hydraulic Techniques**
  - Jet Drilling
  - Flame Jet
  - Rock Heating and Melting
- **Electrophysical Techniques**
  - Plasma Drilling
  - Laser
  - Electric Arc
  - Electron Beam
- **Physical-Chemical Techniques**

# FY 1995 Budget Request

| | |
|---|---|
| ▪ Advanced Slim-Hole Drilling System | $1,500,000 |
| ▪ NADET | $2,000,000 |
| ▪ Downhole Memory Tools, Straddle Packer, & Borehole Televiewer | $2,900,000 |
| TOTAL | $6,400,000 |

# Estimated NADET Funding




Annual Funding

# Estimated Annual Expenditures for Worldwide Drilling and Excavation Activities

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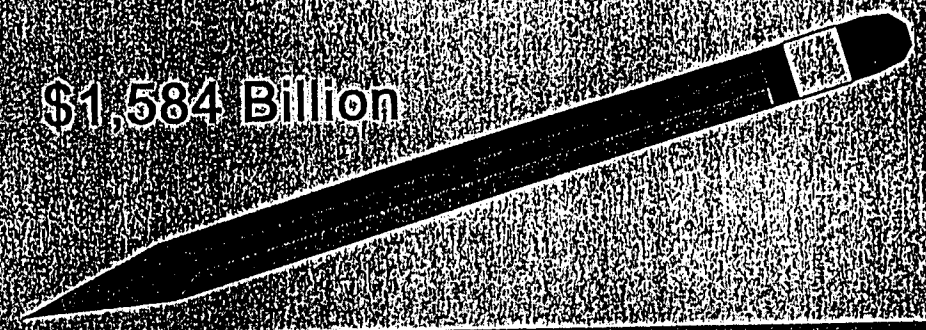


## Appendix E

# Slides Presented by Kenneth Pierce, Sandia National Laboratories

# A Systems Approach to Advanced Drilling

# Basic Functions

1. Energy transmission
2. Rock reduction
3. Rock removal
4. Directional Control
5. Communication
6. Formation maintenance
7. Completion

# System Characteristics

1. Rate of penetration
2. Cost
3. Comparison to current technology
4. Predicted performance and capabilities
5. Technical and financial limitations
6. Industry impact

# Goals

1. Develop a basic reference for advanced drilling systems
2. Identify those concepts most promising for further development

## Appendix F

# Slides Presented by Kevin Crowley, National Research Council

# Drilling and Excavation Technologies for the Future

Committee on Advanced Drilling Technologies

National Research Council
National Academy of Sciences

# COMMITTEE ON ADVANCED DRILLING TECHNOLOGIES

**Ali S. Argon**, Massachusetts Institute of Technology, Cambridge, Massachusetts (*Chair since July, 1993*)

**Neville G.W. Cook**, University of California, Berkeley, California (*Chair until July, 1993*)

**George A. Cooper**, University of California, Berkeley, California

**Michael M. Herron**, Schlumberger-Doll Research, Ridgefield, Connecticut

**Stephen E. Laubach**, The University of Texas at Austin, Austin, Texas

**William C. Maurer**, Maurer Engineering, Inc., Houston, Texas

**James E. Monsees**, PB/MK Team, Dallas, Texas

**D. Stephen Pye**, UNOCAL Corporation, Los Angeles, California

**Jean-Claude Roegiers**, University of Oklahoma, Norman, Oklahoma

**Eugene D. Shchukin**, Institute of Physical Chemistry RAS, Moscow, Russia

**Mark D. Zoback**, Stanford University, Stanford, California

# COMMITTEE ON ADVANCED DRILLING TECHNOLOGIES

Established February 1993
Met 4 times
Drilling Workshop in Washington, D.C. April 93
Attended by 42 experts on all aspects of drilling

## REPORT:

### Examines

Concepts for entire drilling process including:

- State of art in mechanical and non-mechanical drilling mechanisms
- Advances in science of tool-rock interaction
- Advances in drilling tools, motors, coolants, drill string components
- Advances in sensing, guidance, telemetry

### Identifies Opportunities

For long range primary major R&D for secondary R&D for broad front incremental advances

### Recommends

Scope, direction in R&D and means for implementation of recommendations

**DRILLING IS A SET OF PROCESSES FOR BREAKING AND REMOVING ROCK TO PRODUCE BOREHOLES, TUNNELS EXCAVATIONS**

WITH A GOAL TO REACH SUBSURFACE TARGETS **SAFELY** AT THE **SHORTEST TIME** AND **LOWEST COST**

- OFTEN AT GREAT DEPTH IN HARD ROCK;
- INCREASINGLY AT SUBSTANTIAL HORIZONTAL DISTANCES FROM SURFACE DRILLING SITES;
- THROUGH HETEROGENEOUS STRATA
- THROUGH FORMATIONS CONTAINING HAZARDOUS SUBSTANCES

**DRILLING IS A KEY TECHNOLOGY WITH STRATEGIC AND SOCIETAL IMPORTANCE**

- **ENERGY AND MINERAL PRODUCTION**
- **ENVIRONMENTAL PROTECTION AND REMEDIATION**
- **UNDERGROUND INFRASTRUCTURE DEVELOPMENT**

# NATIONAL IMPORTANCE OF DRILLING

- Exploration for and Extraction of oil, gas, geothermal energy, and mineral resources
- Environmental monitoring and remediation
- Underground excavation and infrastructure development
- Scientific studies of the continents and oceans

**Oil Drilling**
$10.9 billion industry; small to moderate size companies;
smaller, less readily detectable reservoirs

**Natural Gas**
20% of primary energy in U.S.
Large potential for growth because of abundance

**Geothermal Drilling**
Needs development; presently not quite competitive with oil and gas

**Environmental Drilling**
$1-2 trillion worth in next 30 years, 1/3 on government weapons complexes

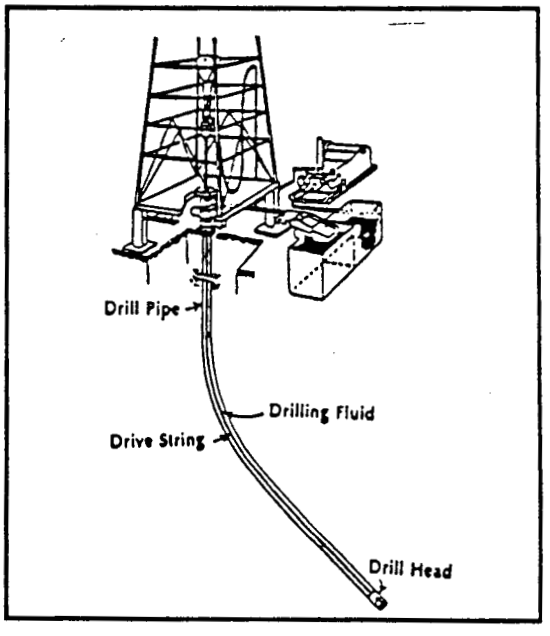
**U.S. Service Companies**
Traditionally strong, small and lean but leadership challenged by subsidized foreign operations is extended reach offshore drilling; deep water drilling, geothermal drilling

**Infrastructure for Underground Services and Mining**
Expanding field of near surface horizontal drilling in and around cities

**Drilling for Scientific Purposes**
On the Continents and Oceans

# THE DRILLING SYSTEM AND THE INTEGRATED SYSTEMS APPROACH

**Complex interdependent sequential processes and interacting component parts**




**Components**

- Drill head, powered from surface or by down-hole motors
- Drill string
- Drilling fluid acts as coolant, medium to transfer cuttings but also medium for drive power, carrier for telemetry

**Processes**

- Rock fracturing or comminution
- Debris removal
- Maintenance of bore hole stability

**System and Process Monitoring**

- Sensing of rock environment ahead of drill, and at drill to avoid bore-hole collapse. Guidance of drill, from surface, or self-guided; monitoring integrity of cutters, drill string, drilling fluid to avoid equipment breakdown

- In an ideal system using an **integrated systems approach** all components and processes function in unison to avoid costly downtime, and failure of parts or worse, **aborting mission.**

- Particular attention to **rate controlling processes** is essential.

## Specific Energy Requirements for Rock Drilling (Maurer, 1968).

| System | Specific Energy (Joules/cc) |
|---|---|
| Rotary Bit | 100 |
| High-Pressure Jets | 1,000 |
| Thermal Spalling | 1,500 |
| Melting | 5,000 |
| Vaporization | 12,000 |

# KEY ELEMENTS OF DRILLING SYSTEM AND AREAS OF POSSIBLE EVOLUTIONARY AND REVOLUTIONARY IMPROVEMENT

| Drilling System Process | Current Status | Anticipated Level of Improvement |
|---|---|---|
| Rock Breaking | Key element in drilling process: bottleneck to increased drilling rate | Evolutionary |
| Debris removal | Potential bottleneck, especially in tunneling | Evolutionary |
| Borehole Stabilization | Discontinuous process | Evolutionary |
| Drill Bit sensing and evaluation | Technology not available | Revolutionary |
| Rock properties sensing and evaluation | Some MWD capability now exists | Revolutionary |
| Drill bit positioning and steering | Notable recent advances in steering | Revolutionary |
| Borehole sensing | Technology not available | Revolutionary |

# RECOMMENDATIONS

## Principal Long Range R&D Recommendation

### SMART DRILLING SYSTEMS
(such systems presently do not exist but are realizable)

- Self guided autonomous system
- Senses rock type ahead of drill and automatically adjusts drilling conditions
- Senses energy or mineral reservoir to be tapped
- Communicates with surface for guidance corrections
- Senses rock conditions at the borehole to avert conditions of bore hole collapse
- Senses and monitors integrity of drill and drill string components to prevent equipment breakdown

To realize smart drills for oil, gas, geothermal and environmental remediation drilling conserted long range R&D is essential.

# REQUIRED R&D FOR SMART DRILLS

**Development of precise connections between measurable rock properties and drilling resistance**

**Development of sensors for smart drills**

- Conditions of rock at drill bit: (pressure, temperature, permeability, mineralogic composition
- Conditions ahead of drill bits: (porosity, elastic properties, wave attenuation)
- Sensors for spatial positioning of drill

**Development of Control Systems**

- For steering
- For adjusting drilling conditions

**Improved Methods for Steering Drill Bit**

**Continuous monitoring of state of drill head and drill string**

**Development of Telemetry Methods**

- bits/second ⟶ Kilobits/sec

**Means for continuous support and reinforcement of borehole**

## SECONDARY RECOMMENDATIONS FOR BROAD SUPPORT OF R&D TO ACHIEVE EVOLUTIONARY ADVANCES

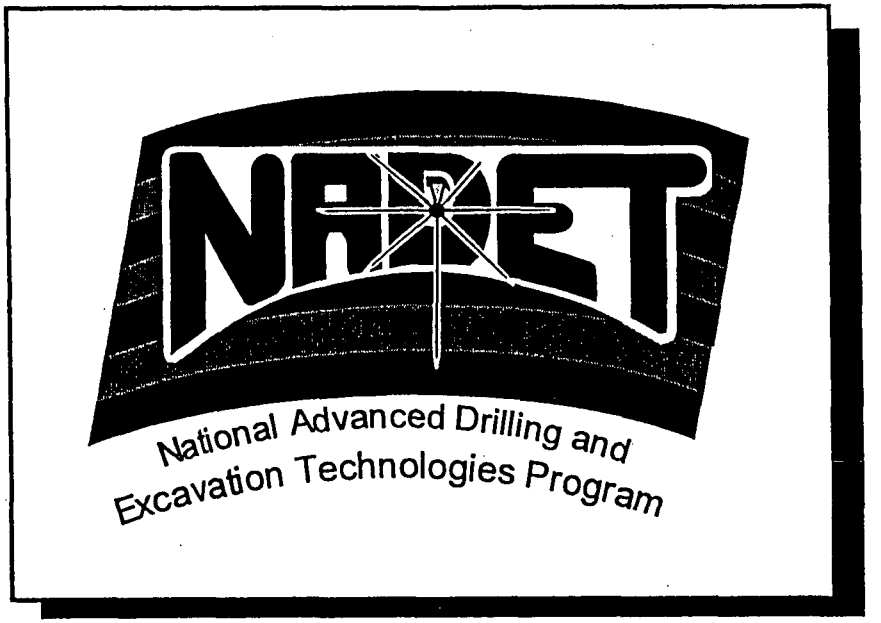
- Re-examination of novel drilling mechanisms with a focus on physics of efficient rock removal
- Improve cutter materials and bearings
- Improved bits for cutting in heterogeneous media with particular emphasis on near surface environmental remediation
- Development of environmentally benign cutting fluids
- Development of durable, compact, high-power down-hole motors for directional and extended range drilling
- Development of flexible drill strings with improved capability for smaller radius turns

## DIMENSIONS OF RECOMMENDED DRILLING PROGRAM

- The proposed R&D must be a **national effort**
- Integration of industry, university and government perspective
- Long term commitment to accomplishments of results is essential
- While industry, academia, and government should be full partners, long term guidance and monitoring of program will require some institutional infrastructure to evaluate proposals, allocate finances and adhere to long range goals.
- Committee has felt that identification of the ideal institutional structure to adhere to the recommended mission with flexibility to nurture the required scientific and technological innovations was outside its charter.

# Appendix G

## Concluding Slides Presented by John "Ted" Mock, Department of Energy Geothermal Division



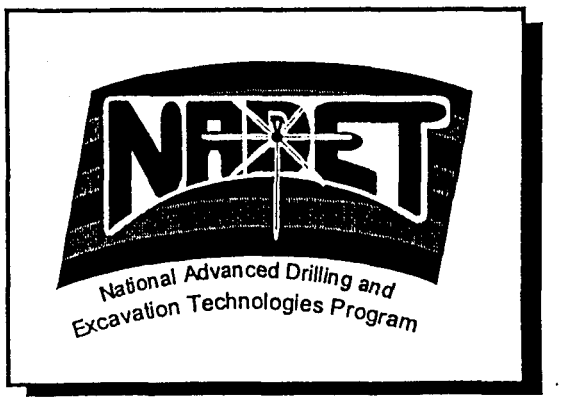

# Proposed Topics for Collaborative R&D

John E. Mock, Director ◉ Geothermal Division
Office of Renewable Energy Conversion ◉ U.S. Department of Energy

*June 24, 1994*

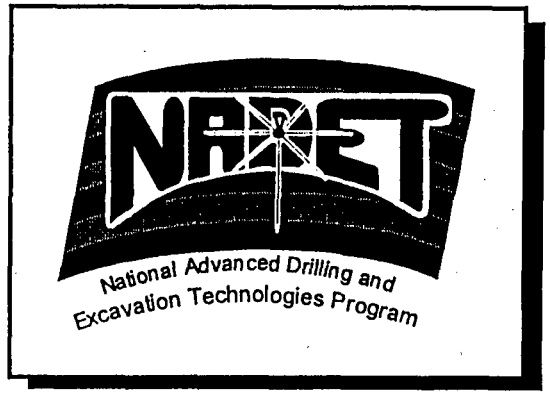
# CONTRIBUTION OF PERFORMANCE IMPROVEMENTS

- Improved Bits
- Improved Drilling Fluids
- Improved Downhole Motors



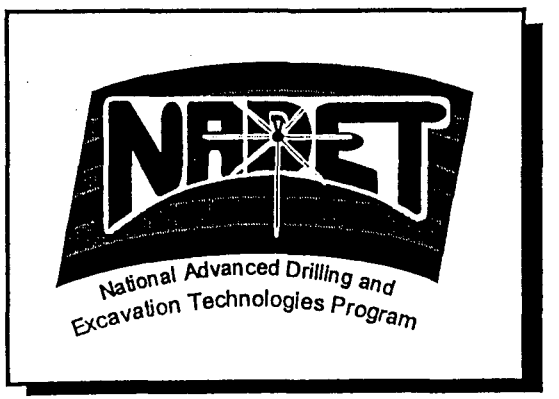
# DRILL BITS

- Greater Rate of Penetration
- Longer Bit Life
- Better Bits for Hard Rock Applications
- Bits that Better Fit Variable Rock Hardness
- Improved Synthetic Diamond Material
- These Sum to a 15% Drilling Cost Reduction



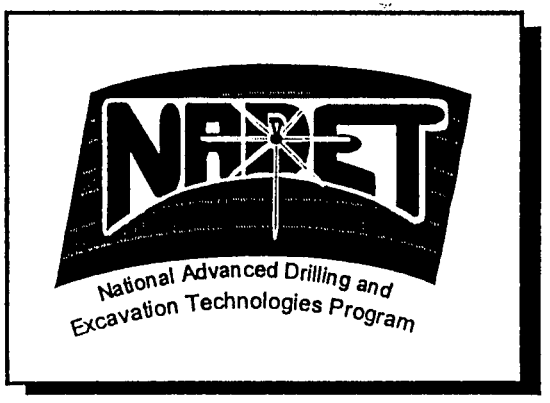
# DRILLING FLUIDS

- Improved Well Bore Stability
- Enhanced Bit Performance
  - Improved Bit Cleaning
  - Improved Hole Cleaning Capability
- These Sum to a 15% Reduction of Drilling Cost



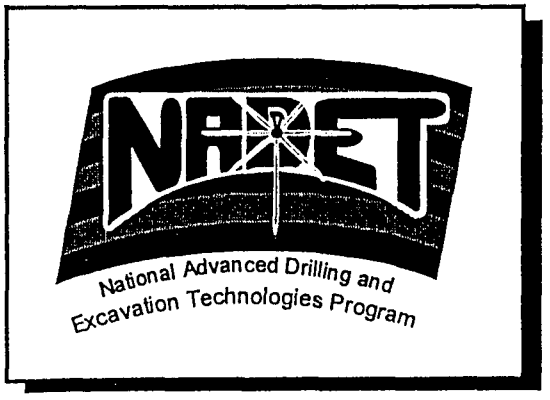
# DOWNHOLE MOTOR

- Improved Reliability/Cost
  - Longer Life Bearings
  - Longer Life Stator for PDM
  - Reduced Repair Cycle Maintenance Cost
- Match Motor to Bit and Formation Requirements
- These Sum to a 10% Reduction in Drilling Cost



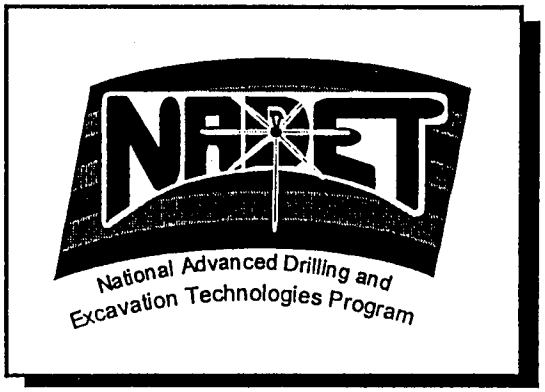
# SMART DRILLING SYSTEM

- Downhole Sensing
  - Drilling
  - Borehole
  - Formation/Resource
- Real-Time Data Transmission/Processing
- Continuous Directional Control



# SMART DRILLING SYSTEM ADVANTAGES

- Optimize Drilling Operations
- Improve Resource Recovery
- Fewer Dry Holes



# IMPACT OF SMART DRILLING SYSTEM

- Reduce Drilling Cost 20%
- Improve Productivity/Well 20%
- Combined 1/3 Reduction in $/BBL for Drilling